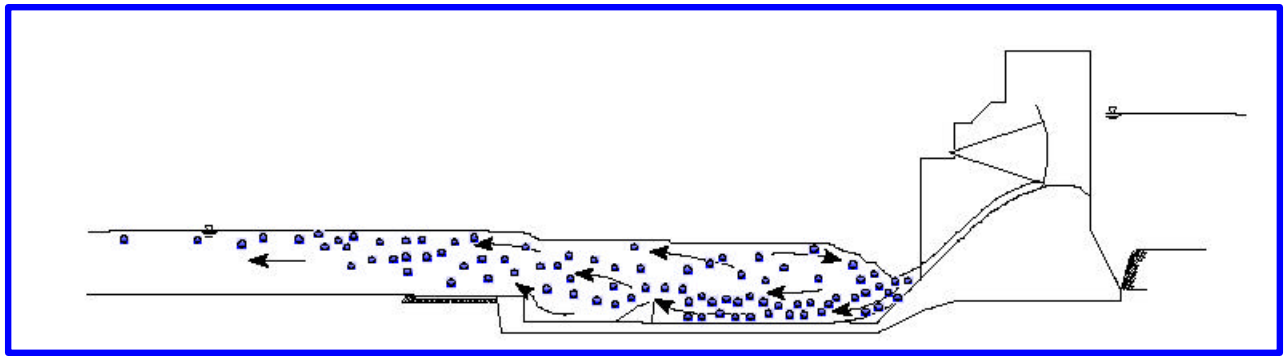
Determination of Total Dissolved Gas Levels below Dams on the Columbia River

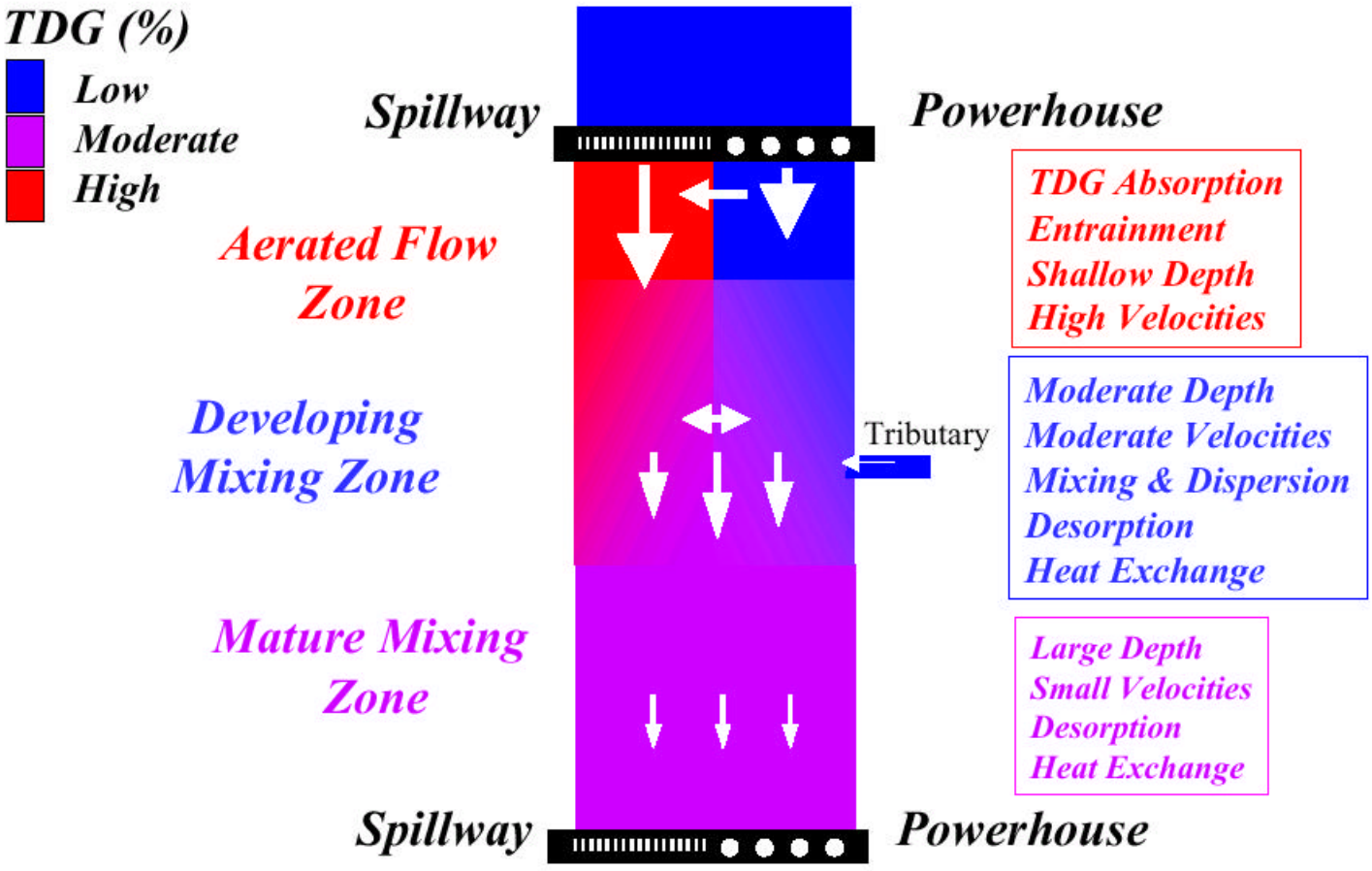
Region 10 Informational Workshop

Portland, OR

July 24, 2001

Basic Process




TDG (%)
Low
Moderate
High
Spillway
Powerhouse
Aerated Flow Zone
TDG Absorption
Entrainment
Shallow Depth
High Velocities
Developing Mixing Zone
Tributary
Moderate Depth
Moderate Velocities
Mixing & Dispersion
Desorption
Heat Exchange
Mature Mixing Zone
Large Depth
Small Velocities
Desorption
Heat Exchange
Spillway
Powerhouse


Columbia River
Powerhouse 2
Spillway
Powerhouse 1
Lock
Bradford
Island
Bonneville Dam
Cascade
Island

Henry's Law

"the weight of any gas that dissolves in a given volume of a liquid, at a constant temperature, is directly proportional to the pressure that the gas exerts on the liquid"

$$p = H_e C_s$$

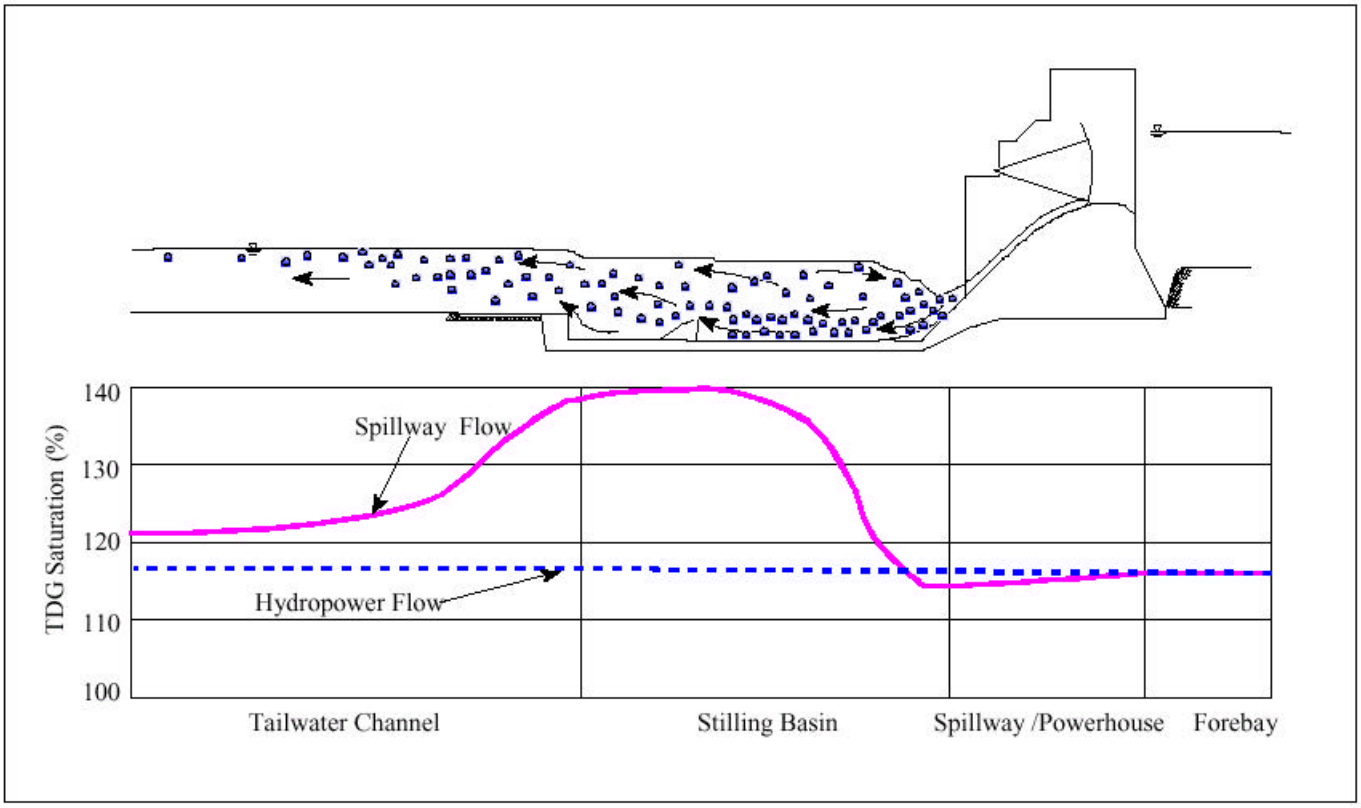
Mass Transfer Rates

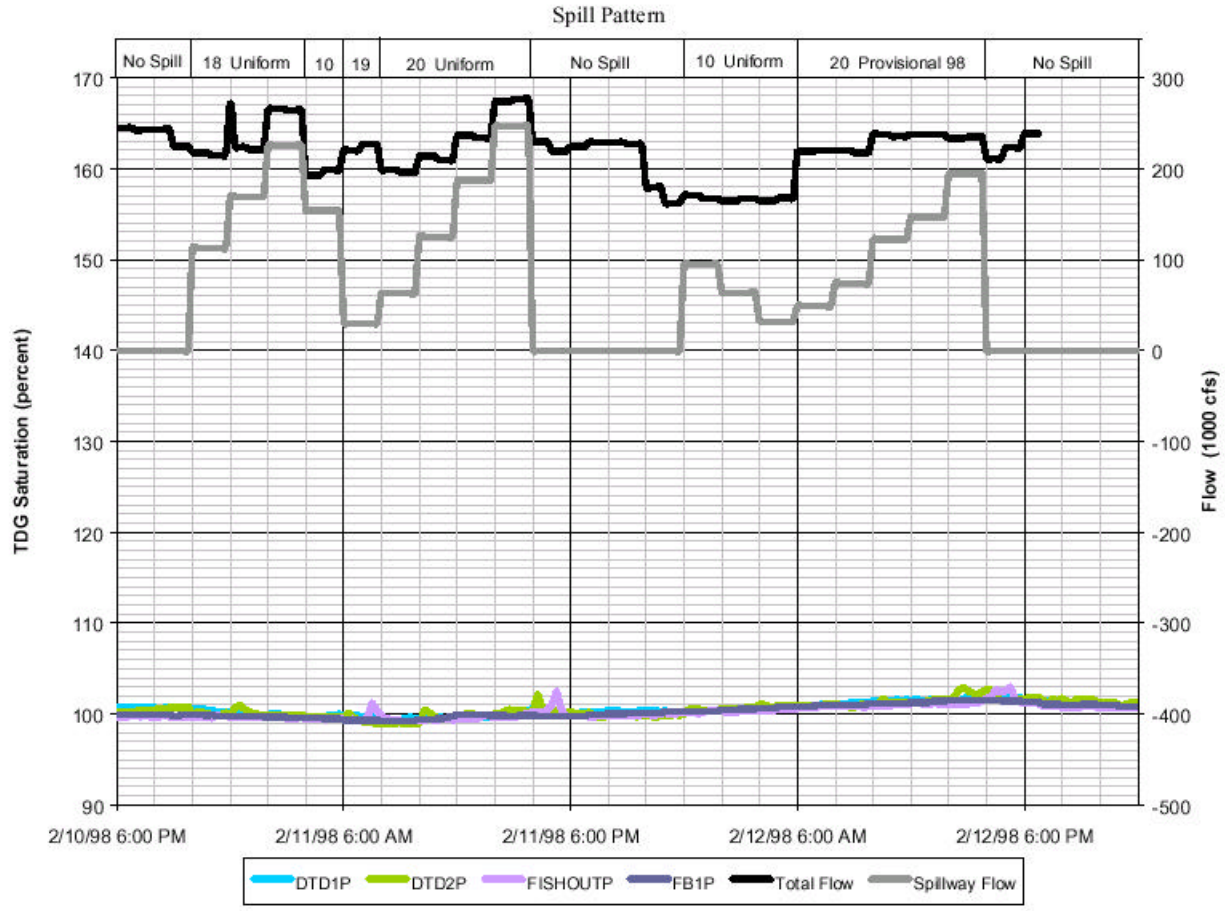
Basic Assumptions for TDG Production

- **TDG exchange is an equilibrium process**
- **Flow through the powerhouse is not exposed to entrained air bubbles (all through spillway)**
- **Powerhouse waters can mix with spillway waters and get exposed to entrained bubbles below dam**

Dissolved Gas Saturation Levels

$$S_{tdg} = \frac{(P_{atm} + \Delta P)}{P_{atm}} \times 100$$


TDG Saturation (%)
140
130
120
110
100
Spillway Flow
Hydropower Flow
Tailwater Channel
Stilling Basin
Spillway /Powerhouse
Forebay


Spill Pattern
No Spill
18 Uniform
10
19
20 Uniform
No Spill
10 Uniform
20 Provisional 98
No Spill
TDG Saturation (percent)
Flow (1000 cfs)
170
160
150
140
130
120
110
100
90
300
200
100
0
-100
-200
-300
-400
-500
2/10/98 6:00 PM
2/11/98 6:00 AM
2/11/98 6:00 PM
2/12/98 6:00 AM
2/12/98 6:00 PM
DTD1P
DTD2P
FISHOUTP
FB1P
Total Flow
Spillway Flow

Determination of Average TDG Pressures

$$P_{avg} = \frac{(Q_{sp} + Q_e)P_{sp} + (Q_{ph} - Q_e)P_{ph}}{Q_{sp} + Q_{ph}}$$

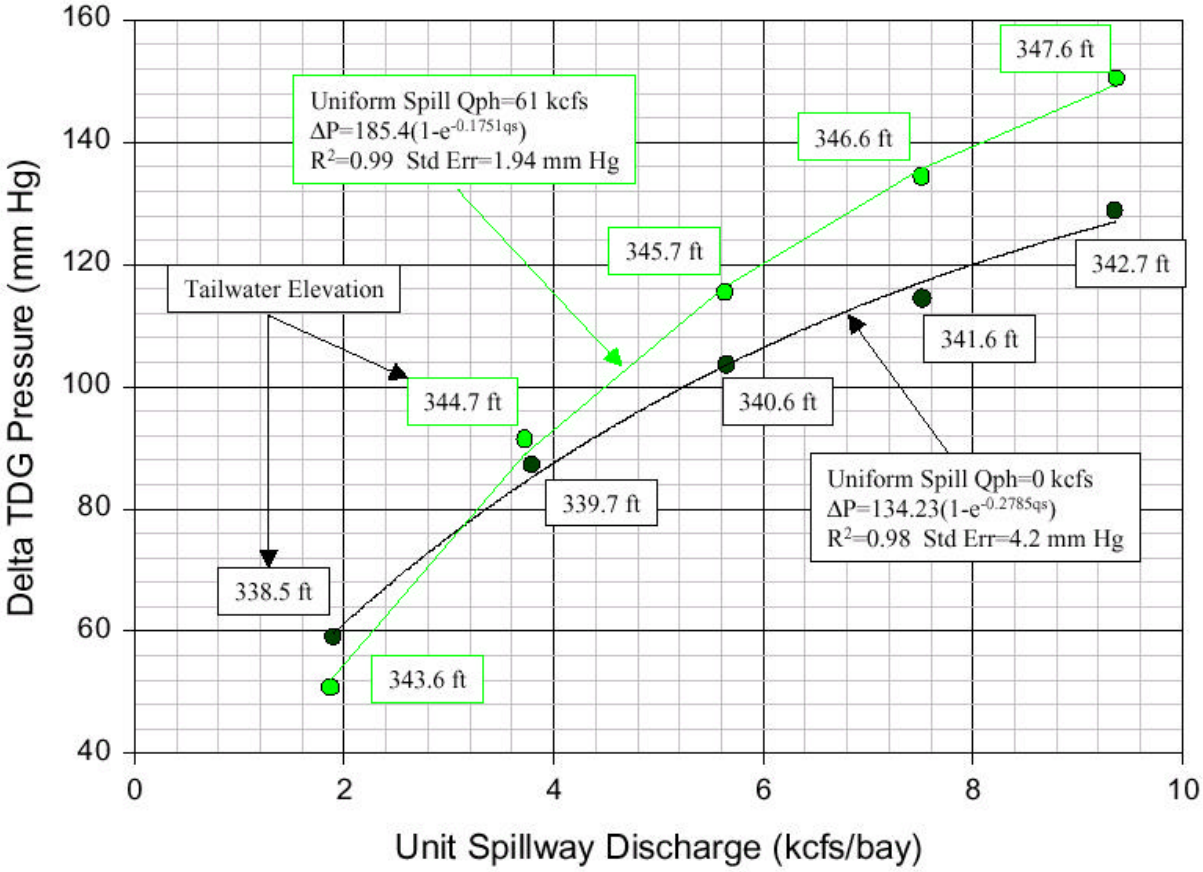

Columbia River
Powerhouse 2
Spillway
Powerhouse 1
Lock
Bradford
Island
Bonneville Dam
Cascade
Island


The Dalles Dam
Powerhouse 1
Spillway
Lock
Columbia River

Calculating TDG

High TDG levels in waters below dams are a function of these key factors:

- **Flow over spillway**
- **Depth of water in tailrace**
- **Amount of powerhouse flow entrained with spillway flow**


Delta TDG Pressure (mm Hg)
Unit Spillway Discharge (kcfs/bay)
160
140
120
100
80
60
40
0
2
4
6
8
10
Uniform Spill Qph=61 kcfs
ΔP=185.4(1-e-0.1751qs)
R2=0.99 Std Err=1.94 mm Hg
Uniform Spill Qph=0 kcfs
ΔP=134.23(1-e-0.2785qs)
R2=0.98 Std Err=4.2 mm Hg
Tailwater Elevation
347.6 ft
346.6 ft
345.7 ft
344.7 ft
343.6 ft
342.7 ft
341.6 ft
340.6 ft
339.7 ft
338.5 ft

Final Formulations

$$\Delta P = C_1 D_{tw}(1-e^{-C_2 q_s}) + C_3$$

$$\Delta P = C_1 D_{tw}{}^{C_2} q_s{}^{C_3} + C_4$$

Use for TMDL Development

- **Empirical coefficients for each dam project determine flow/depth relationship to TDG production**
- **Determination of gas production under various discharge scenrios**
- **Determine allowable flow rate discharge to meet defined TMDL targets**

Questions